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TITLE: Carbon-aluminium@ composite material - consisting of continuous phase with  
specific vol. of pores and carbon@

PATENT-ASSIGNEE: MITSUBISHI KASEI CORP (MITU)

PRIORITY-DATA: 1993JP-0153654 (June 24, 1993)

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ABSTRACTED-PUB-NO: JP07011360A

## BASIC-ABSTRACT:

C-Al composite material in which C, Al or its alloy are continuous phase contains 50-85 vol.% in which 1-40 vol.% pores are present, but contains up to 10 vol.% pores at the outside of C, based on the entire composite material and balance Al or its alloy having coefft. of linear thermal expansion of  $7 \times 10^{-6}/K$  to  $15 \times 10^{-6}/K$ .

USE - For pistons for reciprocal internal combustion engines or seal material used in high temps. or in environment where temps. are changing.

ABSTRACTED-PUB-NO: JP07011360A

## EQUIVALENT-ABSTRACTS:

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**SUZUKI KYOICHI**
(54) **CARBON-ALUMINUM COMPOSITE MATERIAL**

## (57) Abstract:

**PURPOSE:** To provide a carbon-aluminum composite material in which the coefficient of linear thermal expansion is controlled equally to that of a ferrous material as a piston for a reciprocating internal combustion engine and a seal material used in an environment of high temps. or that in which the temp. changes, light in weight and having self-lubricity.

**CONSTITUTION:** The carbon-aluminum composite material in which, in a composite material in which the

phases of carbon and aluminum or their alloy are all formed of continuous ones, the volume content of carbon occupied in the composite material is regulated to 50 to 85vol%, pores are present at the inside of the carbon by 1 to 14vol% to the carbon, the content of pores other than those in the carbon is regulated to 210vol% to the whole body of the composite material, and the balance aluminum or the alloy thereof, and the coefficient of linear thermal expansion is regulated to  $7 \times 10^{-6}/K$  to  $15 \times 10^{-6}/K$  is produced.

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(54) 【発明の名称】 炭素・アルミニウム複合材

(57) 【要約】

【目的】 本発明は、往復型内燃機関用のピストンや高温あるいは温度が変化する環境で使用されるシール材として好適である、線熱膨張係数が鉄系材料と同等に制御され、軽量で自己潤滑性のある炭素・アルミニウム複合材料を提供する。

【構成】 炭素とアルミニウムもしくはその合金がともに連続相である複合材において、該複合材に占める炭素の体積含有率が50～85vol%で、該炭素に対して1～14vol%の気孔が炭素内部に存在し、該炭素の外の気孔が複合材全体に対して10vol%以下で、残りがアルミニウムもしくはその合金であり、線熱膨張係数が $1.5 \times 10^{-6}/K$ 以下、 $7 \times 10^{-6}/K$ 以上であることを特徴とする炭素・アルミニウム複合材料。

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## 【特許請求の範囲】

【請求項1】 炭素とアルミニウムもしくはその合金がともに連続相である複合材において、該複合材に占める炭素の体積含有率が50～85vol%で、該炭素に対して1～14vol%の気孔が炭素内部に存在し、該炭素の外の気孔が複合材全体に対して10vol%以下で、残りがアルミニウムもしくはその合金であり、線熱膨張係数が $15 \times 10^{-6}/K$ 以下、 $7 \times 10^{-6}/K$ 以上であることを特徴とする炭素・アルミニウム複合材。

【請求項2】 請求項1に記載された炭素・アルミニウム複合材からなる往復型内燃機関用ピストン。

## 【発明の詳細な説明】

## 【0001】

【産業上の利用分野】本発明は熱膨張係数が鉄系材料と同等に制御され、軽量で自己潤滑性のある炭素・アルミニウム複合材を提供し、該材料は往復型内燃機関用のピストンや高温あるいは温度が変化する環境で使用されるシール材として好適である。

## 【0002】

【従来の技術】アルミニウムは軽量であるため内燃機関のピストンなどに使用されている。しかし、アルミニウムあるいはその合金は熱膨張係数が $21 \times 10^{-6}/K$ と大きい。一般の鉄系材料の熱膨張係数は $10 \sim 12 \times 10^{-6}/K$ であり、アルミニウムの約半分である。往復型内燃機関ではピストンとシリンダーの間隙が狭いほど燃料の消費効率が良くなる。この間隙は材料の熱膨張係数が小さいほど小さくできる。あるいはシリンダーとピストンの熱膨張率が近いほど間隙は狭くできる。現在シリンダーは鉄系の材料が広く用いられており、軽量のアルミニウム製のピストンの熱膨張係数を鉄系材料と同じにできればメリットは大きい。さらに材料自身に潤滑性があればエンジンオイルを少なくすることができる。

【0003】炭素は自己潤滑性を有するため、回転軸のシール材や固体の軸受けとして使われている。炭素質あるいは黒鉛質粒子を焼き固めた一般の炭素材料は、靱性が低く構造材料として使用するときには信頼性に欠ける。熱膨張係数は $3 \sim 5 \times 10^{-6}/K$ と鉄系材料に比べてかなり小さい。また、炭素繊維で強化した炭素材料であるC/C複合材は強度も高く、また靱性も構造材料に使用できる程度に十分高いが、その熱膨張係数は炭素繊維の熱膨張率に支配され $0 \sim 1 \times 10^{-6}/K$ と非常に低い。また、繊維強化複合材であるためその物性に異方性があり、また、部品としての形状が制約される場合が多く、構造材としては使い難い。シール材や軸受け材が接触する相手の軸には鉄系材料が広く用いられている。しかし、一般の炭素材料あるいはC/C複合材と鉄系材料との熱膨張係数の差は大きく、高温あるいは温度が変化する環境での使用には適さない。

【0004】アルミニウムや炭素製の材料は単独で使用されることは希であり、多くの場合ある部品として他の

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材料と、特に鉄系の材料と組み合わせられて使用される。特に高温あるいは温度が変化する環境で使用される場合、熱膨張係数が鉄系の材料に近いことは重要である。

## 【0005】

【発明が解決しようとする課題】アルミニウムあるいはその合金と、炭素あるいは黒鉛との複合材は軽量で自己潤滑性を有する材料として知られているが、熱膨張挙動に関して既存の材料には以下のような問題点がある。炭素繊維強化アルミニウム複合材の熱膨張係数 $\alpha_c$ は、 $v$ をアルミニウム体積含有率として下記の式(1)で表される。ここで $\alpha_1$ はアルミニウムの熱膨張係数、 $\alpha_2$ は炭素繊維の熱膨張係数、 $E_1$ はアルミニウムの弾性率、 $E_2$ は炭素繊維の弾性率である。代表値として $E_1$ に70GPa、 $E_2$ に250GPa、 $\alpha_1$ に $21 \times 10^{-6}/K$ 、 $\alpha_2$ に $0 \times 10^{-6}/K$ をそれぞれ用い、該複合材の熱膨張係数のアルミニウムの濃度に対する変化を図1の曲線1に示す。

## 【0006】

## 【数1】

$$\alpha_c = \frac{E_1 \alpha_1 v + E_2 \alpha_2 (1-v)}{E_1 v + E_2 (1-v)} \quad \dots (1)$$

【0007】炭素質あるいは黒鉛質粒子を焼き固めた炭素材料にアルミニウムを含浸した複合材では、炭素繊維強化アルミニウム複合材と同様に炭素相とアルミニウム相はそれぞれ連続相であるから、式(1)で該複合材の熱膨張係数は表される。代表値として $E_1$ に70GPa、 $E_2$ に10GPa、 $\alpha_1$ に $3.5 \times 10^{-6}/K$ 、 $\alpha_2$ に $21 \times 10^{-6}/K$ をそれぞれ用い、該複合材の熱膨張係数のアルミニウムの濃度に対する変化を図1の曲線2に示す。

【0008】炭素あるいは黒鉛粒子をアルミニウム中に分散した複合材は、炭素が連続相でないで、炭素質あるいは黒鉛質粒子を焼き固めた炭素材料にアルミニウムを含浸した複合材より、アルミニウムの影響をより強く受ける。したがって、炭素あるいは黒鉛粒子をアルミニウム中に分散した複合材の熱膨張係数は一般に図1の曲線2より大きく、例えば曲線3に代表される変化を示す。

【0009】すなわち、既存の技術ではアルミニウムと炭素を複合した効果が十分に発揮される組成比(アルミニウムの体積含有率が15～85vol%、残りが炭素)では、鉄系材料の熱膨張係数 $10 \sim 12 \times 10^{-6}/K$ を得ることができない。そこで本発明者はこれらの課題を解決すべく鋭意検討した結果、炭素とアルミニウムが共に連続相であって、かつ炭素に適当量の気孔が含まれる複合材により、上記問題が解決できる事を見だし本発明に至った。すなわち、本発明の目的は熱膨張係数が鉄系材料に近く、かつ軽量で自己潤滑性を有する炭素・アルミニウム複合材を提供することにある。

## 【0010】

【課題を解決するための手段】しかしてかかる目的は、炭素とアルミニウムもしくはその合金が共に連続相である複合材において、該複合材に占める炭素の体積含有率が50～85vol%で、該炭素に対して3～10vol%の気孔が炭素内部に存在し、該炭素の外の気孔が複合材全体に対して6vol%以下で、残りがアルミニウムもしくはその合金であり、線熱膨張係数が $15 \times 10^{-6}/K$ 以下、 $7 \times 10^{-6}/K$ 以上であることを特徴とする炭素・アルミニウム複合材により容易に達成される。

【0011】以下に詳しく本発明を説明する。本発明の炭素とは、実質的に炭素原子からなり3次元的に連続である。炭素の形態は特に限定されるものでない。例えば、黒鉛結晶が発達した黒鉛質、黒鉛結晶の発達が悪い炭素質、あるいはX線回折をほとんど示さないアモルファスカーボンやグラッシーカーボンなど、あるいはこれらの混合物などを用いる事ができる。更に具体的には天然黒鉛、人造黒鉛、製鋼用コークス、鋳物用コークス、ピッチコークス、ニードルコークス、カーボンブラック、活性炭などを原料とすることができる。メタン等のガスを熱分化して気相から直接作られた炭素質物質を原料とすることができる。また、炭素の前駆体としてはピッチや熱硬化性樹脂などの有機物を用いることができる。炭素を炭素粒子として用いる場合、一般には0.1～5000 $\mu m$ 程度のものが好適である。

【0012】炭素相が連続でないと大きなアルミニウムの熱膨張の影響をより強く受け、図1の曲線3に示すごとく複合材の熱膨張係数は大きくなり好ましくない。また、炭素に炭素繊維のみを用いると、後述する炭素内部の気孔が本発明の範囲外となり、かつ炭素繊維の弾性率はアルミニウムより約1桁高く、図1の曲線1に示すごとく、炭素繊維の熱膨張率が支配的となり不適当であるが、炭素相に少量の炭素繊維を添加することはさしつかえない。複合材中の炭素の濃度は50～85vol%である。これより炭素濃度が高いと熱膨張係数が小さくなり過ぎるとともに、アルミニウムの含有率が低下するため複合材の靱性が低下するので好ましくない。また、アルミニウムが過剰であると、熱膨張係数が鉄系材料より大きくなり過ぎ、また複合材の自己潤滑性が失われることになる。

【0013】一方、本発明のアルミニウムとは、純アルミニウムもしくはその合金である。アルミニウム合金の熱膨張係数はその組成によりあまり変化しないので、合金の組成は複合材の弾性率等の他の物性により選ぶことができる。唯一の要件は、複合材においてアルミニウムが三次元的に連続していればよい。アルミニウムが不連続であると、複合材の靱性が低下する。周知の様に炭素自身は脆性材料であり、複合材の高靱性はアルミニウムに依存する。このアルミニウムが不連続であれば複合材は脆くなり構造用材料として適当でない。

【0014】炭素中の気孔とは炭素により取り囲まれた気孔である。炭素の熱膨張係数はアルミニウムより小さい。気孔を取り巻く炭素は気孔があるゆえに変形しやすく、アルミニウムの大きな熱膨張を吸収し、式(1)から予想される値より小さな熱膨張係数を実現する。この炭素中の気孔は本発明中最も重要な要件である。気孔量は炭素に対して1～14vol%、好ましくは3～10vol%が良い。炭素中の気孔が多すぎると、炭素相が本来の性質を発現しなくなり不適当である。また、少なすぎると熱膨張係数を制御する能力を失うので不適当である。気孔の大きさは、連続な炭素相に含まれ、かつ炭素相が一つの相として機能する大きさ、すなわち炭素相の代表的大きさの約1桁小さい大きさがその上限として適当である。気孔が炭素原子と同程度の大きさになると、原子欠陥となりもはや気孔として機能しなくなるので不適当である。したがって、炭素中の気孔の大きさは0.01～100 $\mu m$ が好ましい。なお、気孔の形状は特に限定されるものではない。

【0015】炭素の外の気孔とは、炭素とアルミニウムの界面あるいはアルミニウム内部に存在する気孔である。複合材の強度は主にアルミニウムに依存し、炭素の外の気孔はアルミニウムの破壊の起点となり、複合材の強度を低下させる。したがって、炭素の外の気孔量は複合材全体に対して10vol%以下であり、好ましくは6vol%以下がよい。

【0016】本発明の複合材を作る方法として、例えば、内部に適当な気孔を有する炭素質粒子を不活性雰囲気中で焼き固め多孔質体を作り、該多孔質体にアルミニウムの溶湯を含浸する方法がある。得られた炭素・アルミニウム複合材は、炭素とアルミニウムあるいはその合金がともに連続相をなし、該複合材に占める炭素の体積含有率が50～85vol%であり、該炭素に対して1～14vol%の気孔が炭素内部に存在し、該炭素の外の気孔が複合材全体に対して10vol%以下で、残りがアルミニウムもしくはその合金であり、線熱膨張係数が $15 \times 10^{-6}/K$ 以下、 $7 \times 10^{-6}/K$ 以上である。この複合材は常法により成型され、往復型内燃機関のピストン又は各種シール材等として好適に用いられる。

## 【0017】

【実施例】以下に実施例を用いて更に詳細に本発明を説明する。

## 実施例1

炭素質粒子(ピッチコークス、平均100 $\mu m$ )とバインダー(フェノール樹脂)を混合し圧力を加えて成形した後約3000℃で焼成して、嵩密度1.17g/cc、室温から125℃までの平均線熱膨張係数 $4.4 \times 10^{-6}/K$ の多孔質体を得た。この多孔質体の炭素中の気孔を水銀圧入法で測定したところ、炭素に対して約8vol%であった。これに800℃に加熱したJIS H2117(1975)に定められた8種Aアルミニウ

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ム合金 (AC8A) を約800MPaの圧力で含浸して複合材を作った。

【0018】得られた炭素・アルミニウム複合材の室温から125℃までの平均線熱膨張係数は $1.4 \times 10^{-6}/K$ であった。該複合材の断面を走査型電子顕微鏡で観察したところ、気孔はすべて炭素中に存在した。また、該気孔の大きさは約 $50 \mu m$ 以下であった。炭素の密度を $2.2 g/cc$ 、アルミニウム合金の密度を $2.64 g/cc$ として、各工程での重量変化から算出した各構成要素の含有率は、それぞれ炭素53vol%、アルミニウム合金43vol%、炭素中の気孔8vol% (炭素に対して)、炭素の外の気孔0vol%であった。

#### 【0019】実施例2

バインダーとしてコールタールピッチを用いるほかは実施例1と同様の方法で高密度 $1.31 g/cc$ 、室温から125℃までの平均線熱膨張係数 $4.5 \times 10^{-6}/K$ の多孔質体を得た。この多孔質体の炭素中の気孔を水銀圧入法で測定したところ、炭素に対して約4vol%であった。以後実施例1と同じ方法で複合材を作った。得られた炭素・アルミニウム複合材の室温から125℃までの平均線熱膨張係数 $1.4 \times 10^{-6}/K$ であった。該複合材の断面を走査型電子顕微鏡で観察したところ、気孔はすべて炭素中に存在した。また、該気孔の大きさは約 $25 \mu m$ 以下であった。実施例1と同じ方法で算出した各構成要素の含有率は、それぞれ炭素60vol%、アルミニウム合金38vol%、炭素中の気孔4vol% (炭素に対して)、炭素の外の気孔0vol%であった。

#### 【0020】実施例3

平均粒径 $50 \mu m$ のピッチコークスを用いる以外は実施例1と同様の方法で高密度 $1.54 g/cc$ 、室温から125℃までの平均線熱膨張係数 $5.0 \times 10^{-6}/K$ の多孔質体を得た。この多孔質体の炭素中の気孔を水銀圧入法で測定したところ、炭素に対して約5vol%であった。以後実施例1と同じ方法で複合材を作った。得られた炭素・アルミニウム複合材の室温から125℃までの平均線熱膨張係数は $1.1.3 \times 10^{-6}/K$ であった。実施例1と同じ方法で算出した各構成要素の含有率は、それぞれ炭素70vol%、アルミニウム合金28vol%、炭素中の気孔5vol% (炭素に対して)、炭素の外の気孔0vol%であった。

#### 【0021】実施例4

ニードルコークス (平均 $50 \mu m$ ) とバインダー (コールタールピッチ) を混合し押し出し成形した後約3000℃で焼成して、高密度 $1.66 g/cc$ 、室温から12

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5℃までの平均線熱膨張係数 $2.4 \times 10^{-6}/K$ の多孔質体を得た。この多孔質体の炭素中の気孔を水銀圧入法で測定したところ、炭素に対して約5vol%であった。以後実施例1と同じ方法で複合材を作った。得られた炭素・アルミニウム複合材の室温から125℃までの平均線熱膨張係数は $7.8 \times 10^{-6}/K$ であった。該複合材の断面を走査型電子顕微鏡で観察したところ、一部の気孔は炭素中に、残り気孔は主に炭素とアルミニウム合金の界面に存在した。また、炭素中の気孔の大きさは約 $10 \mu m$ 以下であった。実施例1と同じ方法で算出した各構成要素の含有率は、それぞれ炭素75vol%、アルミニウム合金18vol%、炭素中の気孔5vol% (炭素に対して)、炭素の外の気孔4.5vol%であった。以上実施例で得られた炭素・アルミニウム複合材の線熱膨張係数を図1に丸印で示す。鉄系材料の熱膨張係数 $10 \sim 12 \times 10^{-6}/K$ と同じあるいは近い材料が得られる。

#### 【0022】(比較例)

##### 比較例1

20 引張弾性率250GPaのピッチ系炭素繊維とJISH2117 (1975) に定められた8種Aアルミニウム合金 (AC8A) を高圧凝固鑄造法により複合化し、繊維体積分率35vol%、アルミニウム合金体積分率75vol%の一方方向強化アルミニウム複合材を作った。繊維方向に測定した室温から125℃までの平均線熱膨張係数は $7.5 \times 10^{-6}/K$ であった。

##### 【0023】比較例2

30 引張弾性率250GPaのピッチ系炭素繊維とJISH2117 (1975) に定められた8種Aアルミニウム合金 (AC8A) を高圧凝固鑄造法により複合化し、繊維体積分率50vol%、アルミニウム合金体積分率50vol%の一方方向強化アルミニウム複合材を作った。繊維方向に測定した室温から125℃までの平均線熱膨張係数は $5.1 \times 10^{-6}/K$ であった。

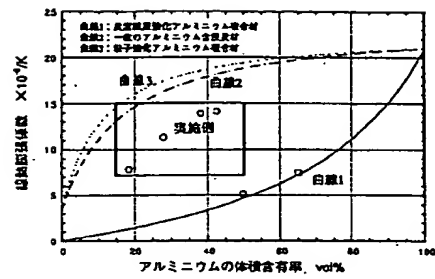
##### 【0024】

40 【発明の効果】本発明は、往復型内燃機関用のピストンや高温あるいは温度が変化する環境で使用されるシール材として好適である、線熱膨張係数が鉄系材料と同等に制御され、軽量で自己潤滑性のある炭素・アルミニウム複合材料を提供する。

##### 【図面の簡単な説明】

【図1】既存の炭素・アルミニウム複合材 (曲線1~3) および本発明による複合材料の熱膨張係数とアルミニウムの体積分率との関係とを説明する。

【図1】





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### (54) CARBON-ALUMINUM COMPOSITE MATERIAL

#### (57)Abstract:

PURPOSE: To provide a carbon-aluminum composite material in which the coefficient of linear thermal expansion is controlled equally to that of a ferrous material as a piston for a reciprocating internal combustion engine and a seal material used in an environment of high temps. or that in which the temp. changes, light in weight and having self-lubricity.

CONSTITUTION: The carbon-aluminum composite material in which, in a composite material in which the phases of carbon and aluminum or their alloy are all formed of continuous ones, the volume content of carbon occupied in the composite material is regulated to 50 to 85vol%, pores are present at the inside of the carbon by 1 to 14vol% to the carbon, the content of pores other than those in the carbon is regulated to  $\leq 10\text{vol}\%$  to the whole body of the composite material, and the balance aluminum or the alloy thereof, and the coefficient of linear thermal expansion is regulated to  $7 \times 10^{-6}/\text{K}$  to  $15 \times 10^{-6}/\text{K}$  is produced.

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### LEGAL STATUS

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## DETAILED DESCRIPTION

## [Detailed Description of the Invention]

[0001]

[Industrial Application] A coefficient of thermal expansion is controlled on a par with iron system material, this invention is lightweight, and offers carbon and an aluminum composite with self-lubricity, and this material is suitable for it as a sealant used in the environment where the piston for gone type internal combustion engines, and an elevated temperature or temperature changes.

[0002]

[Description of the Prior Art] Since aluminum is lightweight, it is used for the piston of an internal combustion engine etc. However, aluminum or its alloy has a coefficient of thermal expansion as large as  $21 \times 10^{-6}/K$ . The coefficients of thermal expansion of a general iron system material are  $10 - 12 \times 10^{-6}/K$ , and are the abbreviation half of aluminum. In a gone type internal combustion engine, the consumption efficiency of fuel becomes good, so that the gap of a piston and a cylinder is narrow. This gap is made so small that the coefficient of thermal expansion of material is small. Or a gap is narrowly made, so that the coefficient of thermal expansion of a cylinder and a piston is near. A merit is large, if the material of an iron system is used widely and a cylinder can make the coefficient of thermal expansion of the lightweight piston made from aluminum the same as iron system material now. An engine oil can be lessened if lubricity is furthermore in the material itself.

[0003] Since carbon has self-lubricity, it is used as the sealant of the axis of rotation, or a solid bearing. The common carbon material which burned and hardened carbonaceous or the graphite particle lacks in reliability, when toughness uses it as a structural material low. A coefficient of thermal expansion is quite small compared with  $3 - 5 \times 10^{-6}/K$ , and iron system material. Moreover, although the intensity of the C/C composite which is the carbon material strengthened with the carbon fiber is also high and it is high enough to the grade which can also use toughness for a structural material, the coefficient of thermal expansion is governed by the coefficient of thermal expansion of a carbon fiber, and it is  $[0 - 1 \times 10^{-6}/K]$ , and ] very a low. Moreover, since it is a fiber strengthening composite, an anisotropy is in the physical properties, and the configuration as parts is restrained in many cases, and it is hard to use as structure material. Iron system material is widely used for the shaft of the partner whom a sealant and bearing material contact. However, the difference of the coefficient of thermal expansion of a common carbon material, or a C/C composite and iron system material is large, and it is not suitable for use in the environment where an elevated temperature or temperature changes.

[0004] The material made from aluminum or carbon of being used independently is rare, and in many cases, it is used as a certain parts, combining it especially with the material of an iron system with other materials. When used in the environment where especially an elevated temperature or temperature changes, it is important that a coefficient of thermal expansion is close to the material of an iron system.

[0005]

[Problem(s) to be Solved by the Invention] Although the composite of aluminum or its alloy, and a carbon or a graphite is lightweight and it is known as a material which has self-lubricity, there are the following troubles in the existing material about thermal-expansion behavior. Coefficient-of-thermal-

expansion of a carbon fiber strengthening aluminum composite. It is expressed with the following formula (I) by making  $v$  into an aluminum volume fraction. It is  $\alpha_1$  here. The coefficient of thermal expansion of aluminum, and  $\alpha_2$  The coefficient of thermal expansion of a carbon fiber, and  $E_1$  The elastic modulus of aluminum, and  $E_2$  It is the elastic modulus of a carbon fiber. It is  $E_1$  as central value. 70GPa(s) and  $E_2$  It is  $21 \times 10^{-6}$  /2 to 250GPa(s) and  $\alpha_1$ . The change to the concentration of the aluminum of the coefficient of thermal expansion of this composite is shown in the curve 1 of drawing 1, using  $0 \times 10^{-6}$ /K respectively. [ K and  $\alpha_2$  ]

[0006]

[Equation 1]

$$\alpha_c = \frac{E_1 \alpha_1 v + E_2 \alpha_2 (1 - v)}{E_1 v + E_2 (1 - v)} \quad \dots (1)$$

[0007] At the composite which sank aluminum into the carbon material which burned and hardened carbonaceous or the graphite particle, like a carbon fiber strengthening aluminum composite, since a carbon phase and an aluminum phase are continuous phases, respectively, the coefficient of thermal expansion of this composite is expressed with a formula (I). It is  $E_1$  as central value. 70GPa(s) and  $E_2$  10GPa(s) and  $\alpha_1$   $3.5 \times 10^{-6}$  /2 The change to the concentration of the aluminum of the coefficient of thermal expansion of this composite is shown in the curve 2 of drawing 1, using  $21 \times 10^{-6}$ /K respectively. [ K and  $\alpha_2$  ]

[0008] Since carbon is not a continuous phase, the composite which distributed carbon or the graphite particle in aluminum is more strongly influenced by the composite which sank aluminum into the carbon material which burned and hardened carbonaceous or the graphite particle of aluminum. Therefore, generally the coefficient of thermal expansion of the composite which distributed carbon or the graphite particle in aluminum is larger than the curve 2 of drawing 1, for example, change represented by the curve 3 is shown.

[0009] That is, in the composition ratio (the volume fraction of aluminum is 15 - 85vol%, and the remainder is carbon) by which the effect which compounded aluminum and carbon with the existing technology is fully demonstrated, coefficient-of-thermal-expansion [ of iron system material ]  $10 - 12 \times 10^{-6}$ /K cannot be obtained. Then, as a result of inquiring wholeheartedly that these technical problems should be solved, both carbon and aluminum were continuous phases, and by the composite by which a suitable quantity of pore is contained in carbon, this invention person found out that the above-mentioned problem was solvable, and resulted in this invention. That is, the purpose of this invention has a coefficient of thermal expansion in near and offering the carbon and the aluminum composite which is lightweight and has self-lubricity at iron system material.

[0010]

[Means for Solving the Problem] A deer is carried out and the volume fraction of the carbon which occupies both these purposes to this composite in the composite carbon, aluminum, or its alloy of whose is a continuous phase is 50 - 85vol%. 3 - 10vol% pore exists in the interior of carbon to this carbon, and the pore besides this carbon receives the whole composite. less than [ 6vol% ] The remainder is aluminum or its alloy and it is easily attained by the carbon and the aluminum composite characterized by line coefficients of thermal expansion being below  $15 \times 10^{-6}$ /K, and more than [ more than  $7 \times 10^{-6}$ /K ].

[0011] this invention is explained in detail below. The carbon of this invention consists of a carbon atom substantially, and is continuation in three dimensions. Especially a carbonaceous gestalt is not limited. For example, amorphous carbon, a glassy carbon, etc. which hardly show the graphite from which the graphite crystal developed, carbonaceous [ with bad development of a graphite crystal ], or an X diffraction can use such mixture etc. Furthermore, specifically let a natural graphite, an artificial graphite, the corks for steel manufacture, foundry coke, pitch coke, a needle coke, carbon black, activated carbon, etc. be raw materials. Let the carbonaceous material which carried out the heat specialization of the gas, such as methane, and was directly made from the gaseous phase be a raw material. Moreover, the organic substance, such as a pitch and thermosetting resin, can be used as a

carbonaceous precursor. When using carbon as a carbon particle, generally an about 0.1-5000-micrometer thing is suitable.

[0012] As it is more strongly influenced of the thermal expansion of big aluminum if a carbon phase is not continuation, and shown in the curve 3 of drawing 1, the coefficient of thermal expansion of a composite becomes large and is not desirable. Moreover, if only a carbon fiber is used for carbon, the pore inside the carbon mentioned later becomes out of range [ this invention ], and the elastic modulus of a carbon fiber is higher than aluminum about 1 figure, and the coefficient of thermal expansion of a carbon fiber becomes dominant, and as shown in the curve 1 of drawing 1, although it is unsuitable, adding a small amount of carbon fiber to a carbon phase will not interfere. The concentration of the carbon in a composite is 50 - 85vol%. Since the content of aluminum falls and the toughness of a composite falls while a coefficient of thermal expansion will become small too much, if carbon concentration is higher than this, it is not desirable. Moreover, a coefficient of thermal expansion becomes it that aluminum is superfluous too much larger than iron system material, and the self-lubricity lubricity of a composite will be lost.

[0013] On the other hand, the aluminum of this invention is a pure aluminium or its alloy. Since the coefficient of thermal expansion of an aluminium alloy seldom changes with the composition, composition of an alloy can be chosen by other physical properties, such as an elastic modulus of a composite. The only requirements should just be continuing in [ aluminum ] three dimensions in a composite. The toughness of a composite falls that aluminum is discontinuous. As everyone knows, carbon itself is a brittle material and it depends for the high toughness of a composite on aluminum. If this aluminum is discontinuous, a composite becomes weak and is not suitable as a structural material.

[0014] The pore in carbon is the pore surrounded with carbon. A carbonaceous coefficient of thermal expansion is smaller than aluminum. Since the carbon which surrounds pore has pore, it is easy to deform, a big thermal expansion of aluminum is absorbed, and a coefficient of thermal expansion smaller than the value expected from a formula (I) is realized. The pores in this carbon are the most important requirements among this invention. the amount of pores -- carbon -- receiving -- 1 - 14vol% -- it is preferably [ 3 - 10vol% of ] good If there is too much pore in carbon, a carbon phase stops discovering an original property, and is unsuitable. Moreover, since the capacity which controls a coefficient of thermal expansion will be lost if too few, it is unsuitable. The size which is contained in a carbon phase [ \*\*\*\* ] and functions as a phase whose carbon phase is one, i.e., a size with the typical size of a carbon phase small about 1 figure, is suitable for the size of pore as the upper limit. Since it becomes an atomic defect and stops already functioning as pore when pore becomes a size of the same grade as a carbon atom, it is unsuitable. Therefore, the size of the pore in carbon has desirable 0.01-100 micrometers. In addition, especially the configuration of pore is not limited.

[0015] The pore besides carbon is pore which exists in the interior of the interface of carbon and aluminum, or aluminum. Mainly, depending on aluminum, the pore besides carbon serves as an origin of destruction of aluminum, and the intensity of a composite reduces the intensity of a composite. Therefore, the amount of pores besides carbon is less than [ 10vol% ] to the whole composite, and less than [ 6vol% ] is preferably good.

[0016] The carbonaceous particle which has the suitable pore for the interior as a method of making the composite of this invention is burned in an inert atmosphere, a hammer-hardening porosity object is made, and there is the method of sinking the molten metal of aluminum into this porosity object. As for both the obtained carbon and the aluminum composite, carbon, aluminum, or its alloy a continuous phase Nothing, The volume fraction of the carbon occupied to this composite is 50 - 85vol%, 1 - 14vol% 14vol% pore exists in the interior of carbon to this carbon, and the pore besides this carbon receives the whole composite. less than [ 10vol% ] The remainder is aluminum or its alloy and line coefficients of thermal expansion are more than  $7 \times 10^{-6}/K$  below  $15 \times 10^{-6}/K$ . This composite is cast by the conventional method and is suitably used as a piston or various sealants of a gone type internal combustion engine etc.

[0017]

[Example] An example is used for below and this invention is explained to it still in detail.

The binder (phenol resin) was mixed with the example 1 carbonaceous particle (pitch coke, an average of 100 micrometers), after applying and fabricating a pressure, it calcinated at about 3000 degrees C, and the porosity object of average line coefficient-of-thermal-expansion  $4.4 \times 10^{-6}/K$  to 125 degrees C was acquired from 1.17g [cc] bulk density and the room temperature. When the pore in the carbon of this porosity object was measured by method of mercury penetration, it was about 8 vol(s)% to carbon. JIS heated at 800 degrees C at this The eight sort A aluminium alloy (AC8A) set to H2117 (1975) was sunk in by the pressure of about 800 MPa(s), and the composite was made.

[0018] The average line coefficients of thermal expansion from the room temperature of the obtained carbon and the aluminum composite to 125 degrees C were  $14 \times 10^{-6}/K$ . When the cross section of this composite was observed with the scanning electron microscope, all pores existed in carbon. Moreover, the size of this pore was about 50 micrometers or less. The content of each component which carried out density of 2.2g [cc] /and an aluminium alloy in 2.64g/cc, and computed carbonaceous density from weight change at each process was pore 0vol% besides carbon pore 8vol% in carbon (as opposed to carbon) aluminium alloy 43vol% carbon 53vol%, respectively.

[0019] The coal tar pitch was used as example 2 binder, and also the porosity object of average line coefficient-of-thermal-expansion  $4.5 \times 10^{-6}/K$  from 1.31g [cc] bulk density and a room temperature to 125 degrees C was acquired by the same method as an example 1. When the pore in the carbon of this porosity object was measured by method of mercury penetration, it was about 4 vol(s)% to carbon. The composite was made by the same method as an example 1 after that. They were average line coefficient-of-thermal-expansion  $14 \times 10^{-6}/K$  from the room temperature of the obtained carbon and the aluminum composite to 125 degrees C. When the cross section of this composite was observed with the scanning electron microscope, all pores existed in carbon. Moreover, the size of this pore was about 25 micrometers or less. The content of each component computed by the same method as an example 1 was pore 0vol% besides carbon pore 4vol% in carbon (as opposed to carbon) aluminium alloy 38vol% carbon 60vol%, respectively.

[0020] The porosity object of average line coefficient-of-thermal-expansion  $5.0 \times 10^{-6}/K$  from 1.54g [cc] bulk density and a room temperature to 125 degrees C was acquired by the same method as an example 1 except using pitch coke of 50 micrometers of example 3 mean particle diameters. When the pore in the carbon of this porosity object was measured by method of mercury penetration, it was about 5 vol(s)% to carbon. The composite was made by the same method as an example 1 after that. The average line coefficients of thermal expansion from the room temperature of the obtained carbon and the aluminum composite to 125 degrees C were  $11.3 \times 10^{-6}/K$ . The content of each component computed by the same method as an example 1 was pore 0vol% besides carbon pore 5vol% in carbon (as opposed to carbon) aluminium alloy 28vol% carbon 70vol%, respectively.

[0021] After mixing and carrying out extrusion molding of example 4 needle coke (an average of 50 micrometers) and the binder (coal tar pitch), it calcinated at about 3000 degrees C, and the porosity object of average line coefficient-of-thermal-expansion  $2.4 \times 10^{-6}/K$  to 125 degrees C was acquired from 1.66g [cc] bulk density and the room temperature. When the pore in the carbon of this porosity object was measured by method of mercury penetration, it was about 5 vol(s)% to carbon. The composite was made by the same method as an example 1 after that. The average line coefficients of thermal expansion from the room temperature of the obtained carbon and the aluminum composite to 125 degrees C were  $7.8 \times 10^{-6}/K$ . When the cross section of this composite was observed with the scanning electron microscope, in a part of pores, the remaining pore mainly existed in the interface of carbon and an aluminium alloy in carbon. Moreover, the size of the pore in carbon was about 10 micrometers or less. The content of each component computed by the same method as an example 1 was pore 4.5vol% besides carbon pore 5vol% in carbon (as opposed to carbon) aluminium alloy 18vol% carbon 75vol%, respectively. A round mark shows the line coefficient of thermal expansion of the carbon and the aluminum composite obtained in the example above to drawing 1 . The same or near material as coefficient-of-thermal-expansion [ of iron system material ]  $10 - 12 \times 10^{-6}/K$  is obtained.

[0022] (Example of comparison)

The pitch based carbon fiber and JIS of example of comparison 1 modulus-of-elasticity-in-tension

250GPa The eight sort A aluminium alloy (AC8A) set to H2117 (1975) was composite-ized by the forging cast process, and the aluminium alloy volume-fraction 75vol% 1 direction strengthening aluminum composite was made fiber volume-fraction 35vol%. The average line coefficients of thermal expansion from the room temperature measured to the grain direction to 125 degrees C were  $7.5 \times 10^{-6}/K$ .

[0023] The pitch based carbon fiber and JIS of example of comparison 2 modulus-of-elasticity-in-tension 250GPa The eight sort A aluminium alloy (AC8A) set to H2117 (1975) was composite-ized by the forging cast process, and the aluminium alloy volume-fraction 50vol% 1 direction strengthening aluminum composite was made fiber volume-fraction 50vol%. The average line coefficients of thermal expansion from the room temperature measured to the grain direction to 125 degrees C were  $5.1 \times 10^{-6}/K$ .

[0024]

[Effect of the Invention] A line coefficient of thermal expansion suitable as a sealant used in the environment where the piston for gone type internal combustion engines, and an elevated temperature or temperature changes is controlled on a par with iron system material, and this invention is lightweight and offers carbon and aluminum composite material with self-lubricity.

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[Translation done.]

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**CLAIMS**

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[Claim(s)]

[Claim 1] In the composite both carbon, aluminum, and its alloy of whose is a continuous phase, the volume fraction of the carbon occupied to this composite at 50 - 85vol% 1 - 14vol% pore exists in the interior of carbon to this carbon, and the pore besides this carbon receives the whole composite. less than [ 10vol% ] The carbon and the aluminum composite characterized by for the remainder being aluminum or its alloy and line coefficients of thermal expansion being below  $15 \times 10^{-6}/K$ , and more than [ more than  $7 \times 10^{-6}/K$  ].

[Claim 2] The piston for gone type internal combustion engines which consists of carbon and an aluminum composite indicated by the claim 1.

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[Translation done.]